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Part 20: Ionizing Radiation/Nonionizing Radiation

20.8
Lasers

(Formerly H&SM Chapter 28)

Recommended for approval by the ES&H Working Group

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New document or new requirements

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20.8

Lasers*

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* Minor **revision**

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Lasers

1.0 Introduction

A laser is a device that produces an intense, coherent directional beam of light energy. LLNL uses many types of lasers—from small lasers used in a laboratory or in the field, to large lasers, such as the National Ignition Facility (NIF). This document describes the different types of lasers used at LLNL, their classifications, and the required controls[1] for each classification. It describes the responsibilities of personnel who work with or supervise laser operations and identifies the training required for all LLNL operations involving laser use. Unless specifically stated otherwise in this document, work standards for the safe operation of lasers and laser systems at LLNL shall follow the recommendations of ANSI Z136.1 -1993, "American National Standard for Safe Use of Lasers-" and ANSI Z136.2 -1997 "American National Standard for Safe Use of Fiber Optic Communication Systems Utilizing Laser Diode and LED Sources." The appendices (within the standards) are not part of ANSI Z136.1 or ANSI Z136.2, and are for informational use only.

This document applies to the operation of lasers at wavelengths between 180 nm and 1 mm in use by LLNL for any experimental or developmental work, and to the personnel who use them at LLNL, both onsite and offsite.

Examples of lasers and laser systems that this document applies to may include

- Commercially available lasers that are used as a part of an experiment or laser development.
- LLNL designed or built lasers or laser systems.
- Applications of any laser or laser system that are determined to be hazardous by the LLNL Laser Safety Officer (LSO), Hazards Control Department or directorate management following an inspection, evaluation or review, based on an intended use or application at LLNL.
- Commercially available lasers that have been modified, assembled or incorporated into a device built by LLNL.

It does not apply to lasers incorporated into commercially available devices for use by the general public, unless opened, serviced, modified, or incorporated into a device

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[1] **Laser users at the Nevada Test Site (NTS) shall also follow the requirements discussed in the *LLNL-NTS Health & Safety Manual* (Volume VI of the LLNL *ES&H Manual*). These procedures contain requirements for the safe use of lasers at NTS and can be obtained through your area ES&H Team.**

built by or for LLNL, or as specifically addressed in this document. Although misuse of these lasers may pose a hazard, it is generally accepted that the risk of injury from these devices is minimal if used as intended by the manufacturer. Examples of these lasers and laser systems not covered by this document include:

- CD players, laser printers, and lasers used in surveying and construction.
- Analytical devices that conform to 21 CFR 1040. Servicing of the installed laser that may expose personnel to hazardous light at LLNL will be required to conform to this document.

This document also includes four appendices:

- Appendix A describes the requirements for warning signs.
- Appendix B discusses safety issues in a laser beam alignment procedure.
- Appendix C tells you how to order laser eyewear.
- Appendix D lists terms and definitions.

2.0 Hazardous Characteristics of Lasers

Using any laser involves exposure to varying degrees of hazards. Most lasers at LLNL can injure the eyes of anyone who looks directly into the beam or its specular (i.e., mirror-like) reflection. In addition, diffuse reflections created by some high-power laser beams can cause permanent eye damage. High-power laser beams can also burn exposed skin, ignite flammable materials, and heat materials so that they release hazardous fumes, gases, debris, or ionizing and non-ionizing radiation.

Note: The most common hazard when working with lasers is eye injury. To prevent such an injury, workers shall avoid looking directly into the laser beam or its specular reflections. This rule shall be followed regardless of the protective eyewear worn or the type of hazard classification of laser unless specifically authorized in an Operational Safety Plan (OSP).

The classification of lasers and laser systems is based on their capability to cause injury. Class 1 (Section 5.0) and Class 2 (Section 6.0) are considered low-hazard lasers. Class 3a lasers (Section 7.0) are considered medium-hazard lasers. Class 3b and 4 lasers (Section 8.0) are considered high-hazard lasers and require more stringent controls.

Equipment and optical apparatus required for producing and controlling laser energy also introduce other hazards, including high voltage, high pressure, cryogenics, noise, additional radiation, flammable materials, laser dyes and solvents, and toxic fluids.

3.0 Pre-work Planning for Lasers

Before the initial use of a laser or laser system, the Responsible Individual shall conduct pre-work planning, including

- Review of the proposed project.
- Completion of a hazard analysis.
- Selection of the necessary controls to minimize exposure.
- Identification of the work procedures to be followed.
- Identification of the personnel who will be conducting the operation, and the materials and hardware to be used.

The level of detail for each step depends on the proposed activity's complexity and degree of risk. Because many controls for lasers are case-dependent, early involvement of the area ES&H Team is essential. The original project decisions may have to be modified after further analysis. For more information on the pre-work planning process, including preparation of an Integration Work Sheet (IWS) and other required documentation, see Document 2.2, "Managing ES&H for LLNL Work," in the *ES&H Manual*.

Pre-work planning, using the IWS, shall encompass the specific hazards of building up a system, including initial laser and optical alignments, connections to power, pressurized systems, etc. See Appendix B and Document 3.4, "Preparation of Work Procedures," in the *ES&H Manual* for considerations in writing a beam alignment procedure.

One critical decision is selecting the class of laser to use for the proposed experiment or operation because the controls differ for each class of laser. Class 4 lasers require the most rigid controls, including preparation of an IWS and a safety plan, because there is greater risk of injury from direct beams, specular reflections, and diffuse reflections.

Class 1 lasers require the fewest controls. More hazardous Class 3b or Class 4 laser systems may be embedded with engineered controls to allow them to be designated as Class 1 laser systems. This can significantly reduce the number of controls involved. (See Section 9.0 for more details).

3.1 Hazard Analysis

Table 1 lists the individuals involved in a hazard analysis and the tasks they shall perform during evaluation of the work and preparation of the IWS. For the use of

Table 1. Performing a Hazard Analysis.

Persons Performing the Task	Task to Be Performed
Project manager, lead experimenter, facility manager, or other person designated as the Responsible Individual (with the assistance of the ES&H Team)	**Determine the hazards involved and the appropriate safety measures and controls required.** **Identify and evaluate the applicable laser hazards, including** • **Laser's capability of injuring personnel.** • **Environment in which the laser is used.** • **Personnel who may use or be exposed to laser radiation.** **Evaluate** • **Laser classification.** • **Conditions of use and beam alignment.** • **Repair methods.** • **Personnel training.** • **Maximum exposure duration.**
ES&H Team, a Laser Safety Officer (LSO), or designated ES&H Team member. (See Sections 15.8 and 15.9)	**Assist in evaluating each operation's degree of hazard and in determining applicable regulations and requirements. This evaluation determines the extent of the hazard analysis, control selection, and documentation requirements for the project.** **The LSO/DLSO calculates a Maximum Permissible Exposure (MPE) for all laser sources based on** • **Laser classification.** • **Exposure duration.** • **Radiated wavelength(s).** • **Output power or energy.** • **Pulse duration and pulse repetition rate if appropriate.** • **Beam size.**
LLNL LSO, Deputy LSO, or Program LSO* (See Sections 15.8 and 15.9)	**Evaluate a laser or laser system if** • **It involves outdoor laser operations or laser operations for public viewing (which are considered unusual conditions) unless the operation is specifically covered by an existing Facility Safety Plan (FSP) or Operational Safety Plan (OSP). Section 11.0 contains additional information on laser use in public areas.** • **A commercially built laser has been modified, embedded, or incorporated into another system (LLNL-built or otherwise).** • **A change in the laser's output could decrease the safety of the system.** **Determine hazard classification of LLNL-built laser or laser system by measurement or calculation of power or energy during operation.** **Recommend appropriate posting and labeling to the controlled area and laser or laser system.**

* **LSO assessments may cover classification or reclassification of the laser or laser system; labeling and posting of the laser based on measurements made during operation, calculations, or information provided by the Responsible Individual. The latter may include reasonable assessments of the maximum potential level of hazards attainable by a laser or laser system without actually requiring a laser to achieve that level.**

Class 1, 2, and 3a lasers, the hazard analysis information will probably fit on the IWS form. For Class 3b and 4 lasers, the hazard analysis document(s) (e.g. laser hazard calculations) may be attached to the IWS.

3.2 Controls for Non-beam Hazards in Laser Areas

Many hazards other than laser radiation can be found in the laser area. The Responsible Individual shall adequately control the hazards to prevent injury while working with lasers. These non-laser hazards are discussed in this section.

Dyes and Solutions. Dye lasers normally use a lasing medium that comprises a complex, fluorescent, organic dye dissolved in an organic solvent. Animal experimentation has shown these dyes to vary greatly in toxicity and carcinogenicity, and several have been found to be mutagens. Treat all dyes as hazardous chemicals (unless it is known that they are not).

In many instances, the solvent in which the dye is dissolved plays a major role in the solution's hazards. Most suitable dye solvents are flammable and toxic if inhaled, ingested, or absorbed through the skin. In the case of dye solutions that are premixed by the manufacturer, make an effort to determine their composition. Dioxane, a potential carcinogen, can form explosive peroxides and, therefore, should be avoided or handled as a carcinogen. See Document 14.12, "Safe Handling of Carcinogenic Materials," in the *ES&H Manual*. Avoid the use of dimethyl sulfoxide (DMSO) and ethylene dichloride.

For additional information concerning the handling of laser dyes and solutions, refer to Document 14.11, "Laser Dyes," in the *ES&H Manual* and the material safety data sheets (MSDSs), or contact the area ES&H Team Industrial Hygienist. Document 14.11 describes the hazard class assigned to laser dyes. A list of laser dyes and their hazard classes are available from the industrial hygienist on your area ES&H Team. A laser dye safety course (HS4242) is available through your ES&H Team or the Education and Training Division of Hazards Control Department.

Electrical Equipment and Systems. The Responsible Individual shall assure that the installation, operation, and maintenance of electrical equipment and systems conform to the standards in Document 16.1, "Electrical Safety," in the *ES&H Manual*. Laser tables shall always be electrically connected to the building ground.

Note: Because interlock switches are energized from a different source than the equipment they control, an interlock switch shall be energized even if the laser equipment is not energized. Older, 110-V interlock systems can remain in use or be moved to a new location; new interlock systems shall operate at or less than 24 V.

Gases Used in Lasers. When toxic gases are used as a lasing medium, exhaust ventilation shall be used to remove gases that could escape into occupied areas. Conditions warranting ventilation at system connections might be filling, purging, or recharging. Review Document 14.3, "Toxic, Corrosive, or Reactive Gases," and Document 12.2, "Ventilation," in the *ES&H Manual* for applicable requirements, or contact your ES&H Team.

Hazardous Materials. Use adequate controls to prevent laser beams and strong reflections from impinging on combustible materials, explosives, highly flammable liquids or gases, or substances that decompose into highly toxic products under elevated temperatures.

Prior to use, conduct or sponsor tests that establish the effects of beam interactions with hazardous materials. Use test results to determine safe parameters for laser operations. Refer to Document 14.1, "Chemicals," in the *ES&H Manual* for other specific controls.

Provide exhaust ventilation when organic or toxic materials are to be vaporized by laser beams. Contact your ES&H Team for guidance or see Document 12.2.

Ionizing Radiation. Contact your area ES&H Team for a safety evaluation before starting a laser operation if it may involve ionizing radiation that originates from the presence of radioactive materials, the interaction of the laser beam with matter, or the use of electrical voltage that exceeds 10 kV. See Document 20.1, "Occupational Radiation Protection," in the *ES&H Manual*.

Non-ionizing Radiation. Electromagnetic fields and radiation may be generated by laser systems or support equipment. Objects, when struck and vaporized by laser beams, can emit non-coherent optical radiation. For specific guidance, contact the area ES&H Team industrial hygienist.

Lighting. Provide adequate lighting in controlled areas.

If the lights are to be extinguished or dimmed during a laser operation, one should

- Install lighting control switches or radio-controlled switches in convenient locations.
- Use luminescent strips to identify equipment, corners of tables, and locations of switches and aisles.

Install emergency lighting wherever the natural lighting is insufficient to allow safe exiting of a laser area during an electrical power failure. More intense room or area lighting may be required for lasers operating at multiple wavelengths in order to compensate for the low visible-light transmission of some laser-protective eyewear.

Pressure Vessels and Systems. All pressure vessels and systems used with lasers, including all toxic gas systems, shall meet the requirements of Document 18.1, "Pressure," and Document 14.3 in the *ES&H Manual*. Vacuum vessels shall be designed to prevent them from becoming pressure vessels during purging or venting operations.

Seismic Safety. After the issue date of this document, optical tables shall be ordered with seismic bracing. Plant Engineering or Mechanical Engineering can also design and install custom seismic bracing for laser tables.

4.0 General Controls for All Lasers

Once the hazards have been evaluated, the Responsible Individual selects appropriate controls tailored to the hazard level. Engineered controls should be used to keep laser light exposures below the maximum permissible exposure (MPE) whenever practical. If engineered controls are impractical, the Responsible Individual may be authorized to use administrative controls. Personal protective equipment is used when engineered and administrative controls provide insufficient protection.

4.1 Operational Safety Plan

For work involving lasers that is not commonly performed by the public, use of the IWS may indicate the need for a written OSP or FSP. Document 3.3, "Operational and Facility Safety Plans," in the *ES&H Manual* provides guidance on how to prepare an OSP. If necessary, contact the area ES&H Team for assistance.

An OSP is required for any laser operation that meets one or more of the following conditions:

- The laser is classified as Class 4.
- The project uses two (or more) Class 3b lasers and any of the following situations exist:
  - — Different operators will control them at the same time in the same area without barriers.
  - — More than one wavelength is present.
  - — Accessible levels greater than 15 mW are used for continuous wave (CW) lasers.
- Non-LLNL personnel (e.g., contract labor or visiting scientists) will use or operate a Class 3b or 4 laser. Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibility, and Integrated Safety Management," in the

ES&H Manual contains additional information on supervision and training of non-Laboratory personnel.

- Unattended Class 3b or 4 laser operations that do not conform to the conditions described in Section 8.4.
- A worker will intentionally directly view a Class 2, 3a, 3b, or 4 laser beam or must use optical viewing aids located close to the beam.
- A Class 3b or 4 laser or laser system will be used outdoor, or offsite when operated or managed by LLNL personnel.
- Lasers or laser systems will be operated jointly with another organization, either on site or offsite.
- The laser operation does not include all mandatory safety controls listed in this document, but the LLNL LSO determines that the operation may proceed.

  Note: This particular authority shall not be delegated to Deputy LSOs or Directorate/Program LSOs.
- ES&H Team or program management determines that an OSP is required.
- The safety interlock system (Section 8.3, "Engineered Controls for Class 3b and Class 4 Lasers," Subsection "Safety Interlocks") either
  - — Is complex (i.e., there are multiple zones whose access status depends on operating configuration).
  - — Does not meet the conditions described in Section 8.3.
- Modification of a Food and Drug Administration (FDA)/CDRH certified system that decreases safety. See Section 12.2 for further information.
- Warning devices that are not listed in Table 2 (or equivalent) are used.

Access panels with liquid crystal displays or light emitting diodes, with equivalent messages, may be used.

OSPs should include or reference plan-view drawings that show the locations of the safety-interlock systems. The drawings should show the location of interlock sensors, such as door switches or floor mat sensors, laser shutters, or power supplies controlled by the interlock system, status displays, panic buttons, and interlock system controllers.

Table 2. Safety access warning panel.

Light color	Audible signal	Laser area status	Meaning
Green	**Silent**	**Class 1, 2, 3a, or 3b (if visible and ≤15mw CW) laser may be in operation.**	**Area is open.**
Yellow (steady)	**Silent**	**Class 3b (except visible CW ≤15mW) or Class 4 laser is ready to operate (i.e., power on, but no exposed beam).**	**Controlled laser area—Entry allowed, but protective equipment shall be carried. See Sections 4.3 and 8.3.**
Yellow (flashing)	**Silent**	**Class 3b (except visible CW ≤15mW) or Class 4 laser in operation. No laser beam hazard present at the entrance.**	**Controlled laser area—Request entry permission. Door interlock system engaged. System will shut down if interlock chain is broken.**
Red (flashing)	**Activated**	**Hazardous remote operation in progress. Used only for unmanned operations.**	**No entry to anyone. Door interlock system engaged. System will shut down if interlock chain is broken.**

4.2 Medical Monitoring

All individuals who work with Class 3b or 4 lasers shall have a baseline eye examination

- Before beginning work with class 3b or 4 lasers or laser systems.
- Following any accidental exposure if an eye injury is suspected.

The Responsible Individual shall notify the payroll supervisor of the need to have a baseline eye examination before beginning work with these lasers. The payroll supervisor or worker shall contact the Health Services Department to schedule this examination.

At the recommendation of the Health Services Department, the Laser Safety Officer (LSO) or Deputy LSO will evaluate the workplaces of personnel with pre-existing eye or medical conditions. The LSO or Deputy LSO will determine if additional controls are needed.

At the time of employment termination, an eye examination by an ophthalmologist is available at the employee's request through the Health Services Department. This examination is not required.

4.3 Personal Protective Equipment

Engineered controls shall minimize the time that personnel spend in proximity to laser beams and their reflections. They shall also minimize the need to work in close

proximity to open beams or hazardous reflections. When engineered controls cannot prevent exposure above the MPE level, personal protective equipment (PPE), such as protective eyewear and clothing, shall be utilized. PPE shall be specified in the safety plan or IWS.

Laser Eyewear. The Responsible Individual, in consultation with the LSO, shall determine the appropriate laser eyewear. Maximum permissible exposure calculations are done based on worst-case situations (intrabeam exposures). Calculated optical densities may not be available (i.e., ODs >7), or it may not be practical to provide protection to MPE values. In that case, the LSO may specify comparable controls to minimize the risk of exposures that exceed the MPE.

A deputy LSO (or the LSO) shall approve all laser eyewear purchases. Industrial Optometry shall approve all prescription spectacles regardless of how the spectacles are ordered. (More information regarding ordering laser eyewear can be found in Appendix C.)

Even when the accessible radiation levels are considered safe, it is good practice for laser personnel to wear eye protection when lasers are in use. Eyewear users shall check the condition of their eyewear before each use and store the eyewear to prevent damage from scratching or contact with water or chemicals during storage. Examples of adequate storage containers can be the pouches or cases supplied with the eyewear, compartmentalized plastic shoe bags from a discount store, felt-lined wooden boxes, or other types of storage containers that protect the eyewear from damage.

Laser eyewear may be used for wavelengths other than those specified by the manufacturer. The required wavelength and optical density information for the particular application shall be either etched into or attached to the eyewear or a graph or data table of wavelength vs. optical density for the eyewear shall be readily available at the location of use.

Laser eyewear should not be subjected to high-intensity beams. High-average-intensity and high-peak-intensity beams can physically damage the lenses, resulting in loss of eye protection. Glass lenses exposed in tests have been shown to crack and shatter up to 15 minutes after high-power laser exposure. Plastic lenses can burn and melt.

High-peak intensity can bleach the eyewear momentarily, allowing hazardous transmission to the eye without causing permanent or obvious damage to the eyewear itself. Because of this effect, special engineering and administrative controls shall be established for lasers with sub-nanosecond pulse widths. Eyewear research data for sub-nanosecond pulse widths is currently limited, but has shown that the effective optical density (OD) rating may be as much as 50% lower than the stated value of the eyewear. This can create a false sense of security that the eyewear will protect the worker from an exposure.

Protective Clothing. In addition to eyewear, some laser operations require protective clothing. This may be based on explicit skin protection calculations made by the LSO or Deputy LSO.

Protective clothing is necessary for those operations in which direct-beam, UV exposures exceed 10 s. Face shields and garments that cover all bare skin shall be worn.

Clothing made from fabrics that are not easily ignited—such as close-knit wool or silk, or commercially available flame-retardant fabrics—should be worn during operations involving exposures to visible and IR lasers where accessible beam irradiance exceeds 2 W/cm^2. When accessible irradiance exceeds 10 W/cm^2, these fabrics shall be worn.

Clothing made of flame-retardant cotton should be replaced after repeated launderings as recommended by the manufacturer. The flame-retardant chemical washes out over time, and laundering opens the weave of the fabric.

Clothing made of cellulose fibers (such as untreated cotton and rayon) should never be used for skin protection.

Contact the area ES&H Team for advice on selecting protective clothing.

4.4 Training

All operators of lasers or laser systems shall read the safety instructions provided by the equipment manufacturer. In addition, laser experimenters who operate Class 2, 3a (except for laser pointers and bar-code readers), 3b, or 4 lasers, or Class 1 laser systems containing embedded Class 3b or 4 lasers, except for commercial instruments that are only serviced by vendor representatives, shall

- Receive a thorough review of the laser equipment to be used from the Responsible Individual. The payroll or program management organizations may require further training.
- Successfully complete Course HS5200-CBT.

  Note: An exam is available in lieu of periodic retraining. Contact the Safety, Education, and Training Section of the Hazards Control Department to schedule the examination.

- Read this document and any relevant OSPs and work procedures.

A laser operator shall meet both the training requirements found in this section, and the operational qualifications specified by the responsible payroll or program management, or in the applicable safety plan.

Although service personnel from offsite are not required to attend LLNL training, the vendors should be able to provide LLNL with proof of laser safety training and other related training that is required for performing the service safely at LLNL. See Document 2.5, "Procured Services Subcontractor Environment, Safety, and Health Program," in the *ES&H Manual*.

4.5 Authorized Operator

The Responsible Individual shall specifically authorize individuals to operate each Class 3b or Class 4 laser or laser system, ensuring that they are medically qualified and properly trained. In addition, the Responsible Individual shall require non-LLNL employers to certify that their personnel meet LLNL's training and operational qualifications as well as the medical monitoring requirements before working with lasers at LLNL.

4.6 Safety Walk-through

All safety interlock systems shall be operational before a laser system is used. Before work begins, a safety walk-through shall occur to verify that work procedures are implemented as specified in the OSP.

4.7 Evaluation of Modified Laser Systems

The ES&H Team and the LSO shall evaluate all modifications to commercial laser systems. Any modifications that decrease the safety controls will require an OSP. Modifications to commercial lasers may require FDA certification or a DOE exemption from FDA certification if the laser or laser system is to be moved offsite. See Section 12.0 for further information about laser modifications and moving lasers offsite. Contact your area ES&H Team for an evaluation as soon you expect the system to be moved offsite.

4.8 Protective Enclosures

Plastic enclosures made by LLNL may be used to reduce the optical density requirements of protective eyewear. The Responsible Individual shall have available the optical density properties of that plastic for the wavelengths of the laser in use. This information can be obtained from the plastic manufacturer's literature, transmission measurements, or other suitable published source on the optical characteristics of the plastic.

5.0 Class 1 Lasers

The number of Class 1 lasers at LLNL is increasing because IR lasers and laser diodes (i.e., lasers emitting wavelengths above 1400 nm) are becoming more common. General-purpose Class 1 lasers are not hazardous. They are incapable of producing harmful accessible radiation or causing a fire. Therefore, Class 1 lasers are generally exempted from most control measures or other forms of surveillance. An exception may be when more hazardous lasers (Class 2 or higher) are enclosed in a protective housing (thus becoming embedded Class 1 lasers). Such a housing shall be labeled to indicate the hazard level of the enclosed lasers and shall either be interlocked or require a tool for removal. See Section 9.0.

Some special-purpose lasers may receive a Class 1 rating because their intended use limits exposure to a nonhazardous level. When such lasers are used for other than their original intent, a hazard evaluation shall be conducted and an IWS shall be developed. Lasers that are not used for their intended purpose may require reclassification.

5.1 Engineered Controls for Class 1 Lasers

The following engineered controls apply to all Class 1 lasers:

Protective Housings. Class 1 lasers shall be placed in protective housings whenever practical.

Beam Control. No beam controls are required.

5.2 Administrative Controls for Class 1 Lasers

The following administrative controls apply to all Class 1 lasers:

Signs and Labels. There are no signs and labels required for Class 1 Lasers.

Beam Alignment and Direct Viewing. A Class 1 laser beam may be viewed directly if the LSO determines that:

- The laser's output still complies with the classification given on the laser hazard label or in the manufacturer's operating manual, and
- The laser is being used as the manufacturer intended.

6.0 Class 2 Lasers

A Class 2 laser emits visible but low-power radiation in either continuous wave (CW) or pulsed visible wavelengths of 400 to 700 nm. CW Class 2 lasers are limited to powers of less than 1 mW.

Natural human aversion time of 0.25-s to bright light provides the necessary eye protection for Class 2-laser users; however, directly viewing the beam of a Class 2 laser for periods exceeding the 0.25-s aversion time may be hazardous. Class 2 lasers do not present a fire hazard.

Typically, scanning systems, such as bar-code scanners, use Class 2 lasers. Although the beams from these lasers are not intended for viewing, they are not hazardous even if an individual views the beam for up to 1000 s.

6.1 Engineered Controls for Class 2 Lasers

In addition to the engineered controls for Class 1 lasers, the following engineered controls apply to all Class 2 lasers:

Beam Control. To minimize the potential for direct eye exposure, observe the following precautions in beam control:

- Enclose laser beams as much as possible.
- Position lasers in such a manner that there is no beam or hazard at the room's entrance.
- Confine all laser beams to a well-defined area of use.
- Mark or block access to areas where beams cross pedestrian or vehicular thoroughfares.
- Terminate the beam at the end of its useful path.
- Position the beam path at a height *other* than eye level whenever practical.
- Block unnecessary beam reflections and remove shiny objects (e.g., jewelry and tools) that may cause unexpected reflections.

6.2 Administrative Controls for Class 2 Lasers

In addition to the administrative controls for Class 1 lasers, the following administrative controls apply to all Class 2 lasers, except for laser pointers and bar-code scanners:

Signs and Labels. Post a hazard warning sign that indicates the work area includes Class 2 lasers, except for laser pointers and bar-code scanners. See Appendix A for requirements for laser hazard warning signs. Warning signs are available from your area ES&H Team.

Beam Alignment and Direct Viewing. Personnel shall never intentionally look directly into the beam of a Class 2 or higher laser without proper authorization. In cases where direct viewing cannot be avoided, the LSO shall conduct a comprehensive safety review (an OSP may be required) and specifically approve the planned work or alignment procedure.

As an alternative, special provisions (e.g., filters, beam expansion, or controls on the exposure time) may be developed to ensure that the beam's intensity is below the MPE for the viewing conditions.

Operator Training. The lead operator shall receive laser safety training and shall assure that other laser users comply with this document.

7.0 Class 3a Lasers

Class 3 lasers are divided into two subclasses (3a and 3b). Class 3a lasers can emit visible or invisible radiation. Normally, their beams are not hazardous when viewed momentarily with the naked eye; but when optical instruments (such as microscopes or binoculars) are used to view the beams, the beams can be hazardous to the eyes. Diffuse reflections of Class 3a lasers are usually not hazardous. A Class 3a laser is not a fire hazard.

Visible Class 3a lasers have accessible output powers up to five times the emission limits of Class 2 lasers. Invisible Class 3a lasers have accessible output powers up to five times the emission limits of Class 1 lasers. Actual values depend on the laser's wavelength, pulse duration, exposure duration, and number of pulses during the exposure duration. Engineered and administrative controls are not applicable to public-use lasers (e.g., those in laser pointers and bar code scanners).

Note: Class 3a laser pointers are covered separately in Section 11.2.

7.1 Engineered Controls for Class 3a Lasers

In addition to the engineered controls for Class 1 and Class 2 lasers, the following engineered controls apply to all Class 3a lasers *excluding Class 3a laser pointers*:

Nominal Hazard Zone. When a Class 3a or higher laser will be operated outdoors or in open areas within buildings, the LSO shall establish a nominal hazard zone (NHZ), or the space around a laser in which exposure to laser light exceeding the MPE is possible. The boundary of the NHZ shall be clearly identified by signs, barricades, walls, tape or ropes, and no laser radiation above the MPE may exist outside the zone.

7.2 Administrative Controls for Class 3a Lasers

In addition to the administrative controls for Class 2 lasers, the controls below apply to all Class 3a lasers:

Signs and Labels. Lasers generating beams with irradiances or radiant exposures below the MPE (e.g., 2.55 mW/cm^2 for visible CW lasers for less than 0.25 s)—including laser pointers—shall be labeled with CAUTION labels. Lasers generating beams with equal or higher power shall have DANGER labels. Labels shall be firmly affixed to the laser or the carrying case in which the laser is stored.

See Appendix A for requirements for hazard warning signs. Warning signs and labels are available from your area ES&H Team.

8.0 Class 3b and Class 4 Lasers

Class 3b and Class 4 lasers are considered *hazardous*. These lasers can cause eye injury so quickly that the natural aversion response will not prevent eye injury. They can also injure the skin.

8.1 Class 3b Lasers

Class 3b lasers have average powers up to 500 mW for CW or repetitive-pulsed lasers. Single-pulse emission levels range from 30 mJ to 150 mJ, depending on the wavelength. Class 3b lasers are hazardous to unprotected eyes and may be hazardous to the skin. Diffuse reflections from Class 3b lasers may also be hazardous, such as when an individual stares at the diffusing surface from within the nominal hazard zone (NHZ).

8.2 Class 4 Lasers

The average power of a CW or repetitively pulsed Class 4 laser can exceed 500 mW. Single-pulse emission levels exceed 30 mJ to 150 mJ, depending on the wavelength. Beams can be either visible or invisible. Class 4 lasers are powerful enough to produce diffuse reflections that could rapidly injure the eyes or skin. Consequently, Class 4

lasers are hazardous to the eyes and skin, whether exposure is to the direct beam of the laser, its specular reflection, or diffuse reflections.

Some Class 4 lasers are capable of igniting combustible materials. As a rule of thumb, lasers emitting more than 2 W/cm^2 are considered ignition hazards.

8.3 Engineered Controls for Class 3b and Class 4 Lasers

Engineered controls specified for Class 2, and 3a lasers also apply to Class 3b and 4 lasers unless the following requirements specifically supersede the requirements for lower-class lasers.

Controlled Laser Area. Class 3b and Class 4 lasers shall only be operated in areas designated for laser operations unless specifically authorized in an OSP. In general, the area should be an enclosed room or laboratory with walls or barriers that block laser radiation.

Controlled laser areas can be divided into sections in which eyewear is required in one section but not in the other. This can occur if the following conditions are met:

- Walls, partitions, or curtains separate the controlled laser area so that beams, specular reflections and hazardous diffuse reflections cannot travel from one section to another.
- The protective eyewear used in all sections has the same wavelength and minimum optical density.
- People passing between sections are required to don laser protective eyewear before entering any other section. Eyewear can then be removed only after verifying that it is safe to do so.
- These controls are included in an OSP.

Temporary Installations. Under some circumstances, it may be necessary to establish a temporary controlled laser area so that laser radiation greater than the MPE does not escape. Mark the entrances to these areas with flashing yellow lights and standard laser warning signs showing the hazard level (i.e., Class 3b or 4) and the characteristics of the exposed laser beams.

Activities requiring temporary control of a laser area may include

- Operating a demonstration laser.
- Performing a short experiment in an uncontrolled location.

- Conducting service adjustments, maintenance, and special training exercises requiring the removal of protective enclosures, equipment interlocks, or other safety devices. Such steps may be necessary to allow entry to a more hazardous class of laser light than the area controls are designed to contain or that affect the operation of some of the area controls.

The LSO shall perform an initial safety evaluation unless the temporary laser installation is already described in an OSP. Because this laser area will not have all the standard safety features, the evaluation shall either indicate the temporary controls necessary to mitigate the hazards or require a new OSP that specifies the duration of the temporary condition.

Multiple Occupancy. To the extent practical, a controlled laser area should have only one laser or laser system. Also,

- When more than one laser or laser system operation is necessary, the appropriate shielding shall be installed, and the conditions of coexistence and methods for maintaining a safe work environment shall be defined.
- If two or more Class 3b and Class 4 lasers are operated in the same area by different operators without intervening barriers, an OSP shall be written and approved.

Access and Spectator Control. Laser laboratories and controlled laser areas shall be designed so that personnel can easily enter and leave these areas during an emergency. Unless approved in an OSP, the doors to controlled laser areas shall not be locked in a manner that makes escape difficult for people inside those areas.

Directorate management, in consultation with the Responsible Individual, should consider maintaining spare keys and a list of active cipher codes required to enter laboratories in their areas. This list and the keys should be controlled and inaccessible to visitors, tours, or unauthorized individuals or groups without proper program management authorization and a valid purpose to enter the laboratory. Examples of authorized individuals who need periodic access to laboratories include the LSO, an Assurance Manager, or Program Safety Officer.

Access to the area during laser operations requires permission from the laser operator. Spectators or visitors shall not enter these areas during laser operations without prior permission from the laser operator and the implementation of appropriate safety measures. The Responsible Individual or lead experimenter (or his/her designee) shall brief these individuals on the hazards and controls used in the controlled laser area.

Safety Interlocks. Controlled laser areas may require a safety interlock system on access panels and doors. Class 3b lasers should include one of the area controls listed below when practical. Class 4 lasers also shall include one these controls.

- *Nondefeatable Area or Entryway Safety Control* (safety latches and entryway or area interlocks such as electrical switches, pressure sensitive floor mats, or motion detectors) shall be used to deactivate the laser or reduce the output levels to the MPE or below should unauthorized entry into the laser area occur.
- *Defeatable Area or Entryway Safety Control* (safety latches and entryway or area interlocks) shall be used if the controls in the previous paragraph adversely affect the intended use of the laser or laser system. If there is no laser light hazard at the entry point the interlock may be bypassed to allow access to authorized personnel provided that they have been adequately trained and provided with adequate personal protective equipment.
- *Procedural Area or Entryway Safety Controls*. Where the above entryway safety controls are not practical or are inappropriate, the following shall apply:
- Authorized personnel shall be trained and the proper eyewear and skin protection shall be provided at the entryway.
- Laser radiation shall be blocked from reaching the entryway, by using screens, partitions, curtains, walls, etc., as appropriate for the laser characteristics. No laser radiation above the MPE shall be allowed to escape the area or expose personnel immediately upon entry.
- The entryway shall have a visible or audible signal indicating that there is a Class 4 laser operating inside. Existing installed laser warning signs or flashing lights on stanchions may satisfy this requirement.

Warning Systems. The activation of a laser shall be proceeded by one or more of the following: a verbal warning or countdown, bells, chimes, lighted status panels, etc. In lieu of any mechanical emission delay, the laser operator shall always make an announcement before laser emission commences to allow workers the opportunity to take appropriate protective action.

Portable rotating or flashing yellow lights mounted on stanchions are commonly used to indicate that a laser operation is in progress with a nonfunctioning interlock system (such as during maintenance by factory service representatives). A sign shall be appended indicating that interlocks are not functioning.

Master Switch Controls. Each Class 3b or Class 4 laser systems shall have a key-controlled, hard-wired master switch (or the equivalent) that prevents laser light

propagation onto the laser table or into the experiment when the key is removed. Keys shall be removed and controlled when the laser system is not in operation.

Safety interlock circuits shall deactivate the laser or use shutters to interrupt the beam. Interlocks shall be designed so that after they are triggered, beam emission cannot occur unless the system is manually reset (or reset in the manner authorized by an approved OSP).

Laser users shall test all safety interlocks at least annually to ensure they are operational. The users shall maintain a written record of each test conducted. An IWS, OSP, FSP, or work procedure may mandate more frequent checks of safety interlock.

Safety Access Warning Panel. When access into a laser area is controlled by an interlock system, a safety access warning panel shall be used. The warning panel shall include lights that indicate the laser area's safety status. The lights on the warning panel shall always be lit whether or not the area is in use. However, when a laboratory is in a safe mode for a prolonged period (such as over night or longer) the panel may turn off as long as (1) instructions are posted that allow immediate verification that the panel is functioning and that the facility is safe, or (2) a notice is attached indicating that no laser activity is being conducted within the laboratory and the interlock system is not required to be maintained or tested. Table 2 lists the purpose for each of the various lights and audible signals.

Red flashing lights shall be used to indicate the occurrence of remote laser operations. Remote operations occur when a laser beam is present in an area that is not under the laser operator's direct observation and control. (See Document 12.1, "Access Control, Safety Signs, Safety Interlocks, and Alarm Systems," in the *ES&H Manual* for more information on remote operations.)

Newer safety access warning panels include light emitting diode or liquid-crystal display indicating the laser area's safety status. Individuals who are inside or outside a controlled laser area where an interlocked warning light or a CAUTION or DANGER sign is displayed may override the safety interlock system to allow access to the laser area under certain circumstances. Interlock system bypass can occur only if the following conditions are met:

- The laser operator authorizes entry into the area.
- No laser beam hazard is present at the entrance. Installation of a partition or other sight barrier just inside the doorway often removes this hazard.
- Individuals who enter the area don the required personal protective equipment prior to proceeding past the door, partition, or other sight barrier.

- Individuals who enter the area are aware of and follow all applicable administrative and procedural controls.
- A maximum 15-s clock is designed into the interlock control circuit to automatically reactivate the safety interlock system after system bypass.
- The external interlock bypass switch is key or cipher-lock operated. The switch may be manually operated to extend the bypass period for special-entry conditions (e.g., to allow the passage of equipment or multiple people).

If the laser area is deactivated (i.e., the laser is removed or stored), the safety access warning panel should be removed or covered with a sign indicating that it has been deactivated.

Beam Mapping. Controlled laser areas shall be surveyed with appropriate measuring devices to locate and identify potentially hazardous direct and reflected beams. Shielding shall be installed to eliminate or reduce such beams to the appropriate MPE level. Particular care shall be taken to locate, identify, and provide shielding of invisible beams from ultra violet or infrared lasers.

A calculation is another method to determine if a direct or reflected beam is hazardous if a measurement is not practical or available.

Beam Controls. Whenever practical, laser beam paths and any potentially hazardous reflections in a controlled area should be enclosed. When it is not practical to fully enclose the laser beam path, the following measures shall be used as appropriate for the specific conditions:

- Terminate any strong reflections and any potentially hazardous transmissions through optics at the end of their useful paths.
- Use non-flammable materials for devices used for backstops, shields, or beam dumps where appropriate with high intensity beams. Mount such devices securely.
- Securely mount the laser system to maintain the beam in a fixed position during operation and to limit beam movement during adjustments.
- Enclose or confine primary beams and potentially hazardous reflections to a well-defined area of use.
- Clearly identify or contain open beam paths on the laser table when practical. The beam should not cross potentially occupied areas or traffic paths if possible. If beams must cross accessible areas beyond a laser table, mark their paths on floors and on tables using red, yellow, or yellow-and-black diagonally striped tape. Beam pipes, chains, ropes, or other barriers may be

used to restrict access through an off-the-table beam. However, they should be designed not to impede egress in an emergency.

- Never point beams toward entry doors (unless the door is used only as an emergency exit or is otherwise inactive).
- When the beam path is not fully enclosed in areas accessible to personnel, design the system whenever practical so that it is outside the normal eye-level range (1.2–2 m above the floor). Pay special attention to areas where the use of desks, chairs, or benches lowers an individual's eyes to the height of the laser table. Orient computer monitors positioned at this height so that they cannot be specular reflectors.
- Avoid directing beams upward from standard optical benches (or into other potentially occupied areas) during either alignment or operational use—unless there is *no* practical alternative. Upward-directed beams are a significant cause of laser injuries. When such beams are necessary, they shall be permanently blocked at the end of their useful path. Such beam paths shall be labeled or posted to indicate the hazard.

The addition of beam-stopping panels at the sides of optical tables or entire beam path enclosures of Class 3b and Class 4 lasers is recommended as a general safeguard against improperly aligned laser beams or reflections.

The material used to make beam enclosures for Class 4 lasers shall be fire-resistant.

Reflection Control. Wherever possible, utilize materials that are diffusely reflective or have a low reflection coefficient in place of specularly reflective surfaces. Specularly reflective surfaces that are needed in the vicinity of beams should be enclosed or shielded to minimize personnel exposure. Non-reflective tools should be used, whenever practical.

Badges, jewelry, and other reflective personal items shall be removed or covered during laser alignment or other work near laser beams. Keep laser areas as free as possible of unnecessary clutter. Laser users shall remove unnecessary tools and equipment from laser tables.

Invisible Beams. Ultraviolet and infrared lasers that emit invisible beams require the following additional controls:

- Visual or audible indicators of beam emission shall be used in areas where laser radiation exceeds 10-second MPE. Indicators shall be clearly identifiable from anywhere in the controlled laser area. They may include the laser firing noise, status panels, or the fluorescence caused by laser light hitting an absorbing surface. The indicators shall be easily detectable under all normal operating conditions, and visible when laser eyewear is worn.

- Areas where personnel may be located during normal activities shall be shielded to limit UV radiation below the skin MPE.
- Beam stops shall be made of material that absorbs or diffusely reflects the laser's invisible radiation.
- Viewing aids, such as IR and UV cards and viewers, shall be used during alignment.

  Note: Laminated viewing cards may be specular reflectors, so caution is needed while using them.
- If in doubt, measurements shall be taken or calculations shall be made to confirm that invisible radiation is controlled in the area.
- Methods shall be implemented to remove hazardous by-products formed by intense radiation reacting with materials in the area.

Optical Viewing Aids That Concentrate Light. Use of optical systems such as cameras, telescopes, microscopes, and endoscopes to view laser beams may be hazardous to the eye. Therefore, all optical instruments intended for viewing a laser or laser system should be equipped with suitable means (e.g., filters, attenuators, or interlocks) to preclude transmission of laser light exceeding MPE to the eye. The selected equipment shall prevent transmission under all conditions of operation and maintenance.

Note: Normal prescription eyewear does not fall into this category.

Fiber Optics. Fibers used to deliver high-power laser light have the potential of burning through standard fiber sheathing if the fiber is broken. Incorporate special design controls to protect the fibers from damage as well as exposure to laser radiation. Keep flammable and combustible materials away from fibers carrying high-power laser radiation. When practical, fiber optic cables should have an armored or fire-proof cladding. Trays, cabling, or enclosures should be appropriately identified with a laser hazard label.

ANSI Z136.2 only applies to systems where the radiant energy is confined within an optical fiber during intended use. This standard provides guidance for the safe use, maintenance, and service of optical fiber communications systems (OFCS) that use laser diodes or light-emitting diodes operating at wavelengths between 0.4 and 2.6 μm. Refer to ANSI Z136.1 for laser-transmitting fibers that do not meet these criteria.

8.4 Administrative Controls for Class 3b and Class 4 Lasers

Administrative controls specified for Class 2 and 3a lasers also apply to Class 3b and 4 lasers unless the following requirements specifically supersede the requirements for lower-class lasers:

Signs and Labels. The outside of the laser enclosure shall be posted with hazard warning signs specifying the highest laser class in use. Also,

- Attach a laser classification label (if no manufacturer label exists) in a conspicuous location on or near the laser housing.
- Post DANGER signs at each entrance to the operating area. The hazard warning sign should indicate that the work area includes Class 3b or Class 4 lasers.
- Keep the signs and labels current and legible.

See Appendix A for requirements for hazard warning signs. Warning signs and labels are available from your area ES&H Team.

Safety Evaluation of Direct Viewing. When direct viewing cannot be avoided, the LSO shall conduct a safety evaluation and specifically approve the work or alignment procedure for direct viewing.

Additionally, when the beam of a Class 2, 3, or 4 laser shall be viewed directly on purpose, or if it is necessary to work with optical viewing aids close to the beam, the Responsible Individual shall prepare an OSP. In these cases, special provisions (e.g., use of filters or beam expansion) are mandatory to reduce exposure below the MPE.

Beam Alignment. Alignment is the most hazardous laser activity because personnel must override the engineered and administrative safeguards. Therefore, laser optical systems (e.g., mirrors, lenses, and beam deflectors) shall be aligned in a way that minimizes the possibility of exposing the eye or skin to the laser beam (or the beam's specular or diffuse reflection) above the MPE.

For complex processes the Responsible Individual should develop an alignment procedure for Class 3b and Class 4 laser systems addressing the applicable issues listed in Appendix B. This alignment procedure may either be included in the laser's OSP or kept in an easily accessible place by the laser operators. The alignment procedure shall be reviewed whenever the OSP is reviewed, or when changing laboratory conditions warrant the need for a review. Document 3.4 contains general information on the preparation of safety related procedures.

Laser operators should consider techniques for performing safe alignments, such as the following:

- Viewing the laser with a TV camera.
- Viewing the laser with an image-converter viewer.
- Using a low-power alignment laser.
- Reducing the primary beam power.
- Inserting fluorescent materials into the beam.

Additionally, the laser operator shall announce that a loose beam is going to be projected into the laser laboratory or area so that others in the area can protect themselves by donning eyewear, leaving the area, or asking for a delay until they can protect themselves. This announcement shall be made even if the area appears empty (unless personnel cannot enter without the operator's knowledge).

Under certain conditions, and after consultation with and approval by the LSO, protective eyewear worn when aligning *visible* lasers at wavelengths greater than 450 nm may be reduced by a maximum of 1.2 optical density (OD) from the calculated values of optical density or those in the "Eyewear OD" column of the lasers table in the OSP (as applicable) to allow the beam to be seen. These special *alignment* glasses shall be conspicuously marked, indicating that they are to be worn for alignment purposes only and stored separately from the other eyewear in the lab.

> **The laser operator shall take special care to avoid exposure to direct beams or reflections because the optical density of the alignment eyewear may be sufficiently low that it admits hazardous levels of light from a direct beam or reflection that could permanently damage the eyes.**

Measures shall be taken to ensure that no stray hazardous specular reflections are present before the lower OD eyewear is worn. These measures shall be documented in an alignment procedure. The minimum OD allowed is determined by a calculation for diffuse viewing at 0.5 m. The laser operator should use the highest OD that will permit successful completion of the alignment task.

> **When the alignment is completed, the normally specified full eyewear OD shall be worn.**

Eye Protection. Everyone within a controlled laser area or a NHZ shall use eyewear that meets the laser eyewear requirements. See "Laser Eyewear" in Section 4.3 for information on the eyewear safety. Purchase new eyewear if there is no available eyewear or if available eyewear has deteriorated.

Remote Operation. The Responsible Individual shall sweep a remotely operated area before it is illuminated to ensure that it is unoccupied. Otherwise, visible and audible warnings of the impending safety-status change shall be made, followed by a countdown to the status change.

Unattended Laser Operation. Except for visible CW 3b lasers ≤15 mW, an operating laser is considered unattended if none of the authorized operators is in the controlled laser area or at the remote operating station. If an unattended laser is not in use, its power supply shall be de-energized and the keys removed from the power switches or master interlocks,-or the laser area shall be locked to prevent access.

If an authorized operator is not available, the following requirements for unattended laser operation apply:

- The Responsible Individual shall conduct an analysis with assistance of the ES&H Team to determine the necessary controls and ensure their implementation.
- During other than normal working hours, the operator shall notify the Emergency Management Division (Fire Department) dispatcher by dialing business line (ext. 2-7595). Ask the dispatcher to notify the Fire Department and the off-shift health and safety technologist that an unattended laser is operating in your building and room.
- The laser system shall include functional lights and audible signals or signs indicating that it is operating and utilizes an interlock system, if required. See Table 2 for more information.
- In addition to any required laser warning signs, the entrance signs shall indicate who should be notified if an emergency occurs and how to make the area safe (shutdown instructions) if emergency response is required. See Appendix A for unattended laser signs.

If these requirements cannot be met, an OSP will be required for unattended laser operations.

Maintenance/Adjustment. Personnel performing maintenance or adjustment tasks on Class 3b or 4 lasers or laser systems shall be informed of the risks involved either through posting signs at the laser system's work area, providing direct supervision, or by including warning information for maintenance and service personnel in the maintenance instructions.

System Check. Safety systems that may have been bypassed, tampered with, or de-energized to allow maintenance or adjustments (especially by outside vendors or service representatives) shall be tested or inspected to ensure these systems are working properly before the laser is returned to service. Record this test on the interlock check sheet for the laser.

9.0 Class 1 Laser Systems with More Hazardous Embedded Lasers

A laser system can be converted to a Class 1 system by including in the laser system design all the controls described in this section. These controls will effectively enclose the laser, prevent personnel contact with the emitted radiation, and permit unrestricted access into the area.

9.1 Engineered Controls for Class 1 Embedded Lasers

The following engineered controls apply to all Class 1 laser systems with more hazardous embedded lasers.

Protective Housing. A protective housing that encloses the embedded Class 3b and Class 4 lasers (beam tubes, covers, etc.) and their output shall be used to prevent the escape of laser radiation above the Class 1 MPE level into areas where personnel have access during normal operations.

Housing Interlocks or Alternative Controls. The protective housing and its access panels or doors shall either be interlocked or shall require tools for removal as approved by the LSO. If an enclosure surrounds live, high-voltage parts, it shall be equipped with a fail-safe interlock system that turns off the high voltage when the enclosure is opened.

In instances where a Class 1 embedded laser is housed in a walk-in enclosure, interlocks are required to prevent operation with personnel inside the enclosure. Service adjustments or maintenance work performed on the laser system shall not render the interlocks inoperative or cause exposure levels outside the enclosure to exceed the MPE unless the work is performed in a laser area with limited access, appropriate safeguards, supervision, and controls. Preparation of an IWS may indicate the need for work procedures or an OSP.

Fail-safe Design. When interlocks are used, the protective housing and the laser system shall be designed and fabricated so that the system will continue to meet the requirements for a Class 1 enclosed laser operation if a failure occurs.

Attenuated Viewing Windows (Portals). Viewing windows shall contain a suitable filter material that will attenuate the transmitted laser radiation to levels below the appropriate MPE under all operating conditions.

9.2 Administrative Controls for Class 1 Embedded Lasers

Signs and Labels. The outside of the laser enclosure shall be posted with a label that specifies the laser classification of the embedded laser. Additionally, the service access panels shall have similar labels.

See Appendix A for requirements for hazard warning signs and labels. Warning signs and labels are available from your area ES&H Team.

Note: Commercial equipment with embedded lasers will often include warning information in the instruction manual.

Maintenance/Adjustment. Personnel entering the laser enclosure to perform maintenance or adjustment tasks shall be warned of the risks involved. This warning can be in the form of a label on the laser system's protective housing, direct supervision, or warning information included in the user instructions for maintenance and service personnel. Affected personnel shall comply with the control measures for the higher-hazard laser class.

System Check. Safety systems that may have been bypassed, tampered with or de-energized to allow maintenance or adjustments, especially by outside vendors or service representatives, shall be tested or inspected to ensure these systems are working properly before the laser is returned to service. Record this test on the interlock test sheet.

10.0 Optical Fiber Systems

10.1 Engineered Controls

Lasers or laser systems that use optical cables to transmit light from one laser area to another shall be considered an enclosed system, with the optical cable forming part of the enclosure. If disconnecting a connector results in accessible radiation above the MPE level, then appropriate engineered and administrative controls consistent with the hazard classification shall be applied.

10.2 Administrative Controls

When hazardous radiation levels may be present at the end of optical fibers, a CAUTION or a DANGER label (as determined by the ES&H Team or LSO) shall be attached near the end of the fiber or fiber holder. The optical fiber shall be capped off when not in use.

11.0 Laser Use in Public Areas or Uncontrolled Areas

Certain hazardous lasers, including hand-held bar-code readers and laser pointers, are commercially available to people with no technical training. LLNL personnel responsible for any of these devices shall read the following paragraphs in this section and the manufacturer's safety instructions.

11.1 Outdoor Use of Lasers

Lasers and laser systems used outside shall be evaluated by the LSO, except for the use of commercially available lasers in surveying and construction. Lasers that are directed above the horizontal into navigable airspace require advanced notification and approval from the Federal Aviation Administration if there is a possibility of hitting an aircraft with the beam. The LSO can provide assistance in getting this approval.

11.2 Laser Pointers

New laser pointers and bar-code scanners now often use Class 3a lasers, as defined by American National Standard Institute (ANSI) Z136.1-1993, "American National Standard for Safe Use of Lasers." Previously, Class 2 lasers were used; these are low-power lasers that are safe to view unless the viewer suppresses the urge to blink and stares into the laser beam.

Class 3a lasers are, however, moderately powerful and can be hazardous even if viewed for only a brief period of time. Class 3a lasers have a DANGER label; Class 2 lasers have a CAUTION label. When handling Class 3a laser pointers, hand-held bar-code scanners, and other lasers, observe the following precautions:

- Never point a laser at anyone.
- Never stare into the beam.
- Never view a laser beam using an optical instrument (such as binoculars or microscopes) unless the work procedure has been reviewed and is covered by an OSP or hazard assessment. Use of an optical instrument to view a laser beam can sometimes make a safe exposure dangerous.

Class 3a red diode laser pointers have been on the market for years, but Class 3b red pointers are now advertised on the Internet and are more readily available. Class 3b green laser pointers have also recently appeared in the marketplace. Class 3b pointers have sufficient energy to cause eye injuries, even during brief exposures. They are dangerous lasers. Higher power green laser pointers are manufactured in the former Soviet Union and the People's Republic of China and can sometimes be recognized by the lack of customary laser warning labels. DANGER labels should feature a starburst

pattern with a "tail" pointing far to the right of the starburst as required by the Food and Drug Administration's regulations. Class 3b laser pointers may not be sold legally in the United States and shall not be used at LLNL.

A label on a laser pointer is no guarantee that the manufacturer has complied with accepted output power level limits. Improper use or modifications of these devices may cause injury. However, when laser pointers are used for their intended purpose, personnel exposure is nonexistent because the laser beam is directed away from the audience.

LLNL personnel responsible for meetings, such as chairpersons or session arrangers, shall ensure that the laser is not pointed at the audience. If this occurs, they shall advise presenters that the beam is potentially hazardous and shall not direct the beam at the audience. Only one laser pointer may be used at a time. Attendees shall not use pointers while seated because members of the audience or the speaker may look into the laser beam.

Make sure all laser pointers retain their DANGER or CAUTION labels. Visible CW lasers generating beams with irradiances or radiant exposures below the 0.25 s MPE (or 2.55 mW/cm^2) shall have CAUTION labels. Lasers generating beams with equal or higher powers shall have DANGER labels. The label should be firmly attached to the laser pointer or the laser's carrying case.

Because it is now possible to purchase these dangerous lasers, the following actions shall be taken:

- Class 2 diode laser pointers are available and should be used instead of Class 3a laser pointers, whenever practical.
- *Never* purchase or use a Class 3b laser pointer at LLNL.
- Never purchase a laser pointer unless it has the FDA-mandated CAUTION or DANGER safety warning label.

12.0 Lasers Sent Offsite

Individuals who ship lasers offsite, including drop shipments, are cautioned to begin the authorization process as soon as they are aware that an offsite movement will be involved so the shipment will not be held up. Authorizations may be required of several institutional organizations, such as the LLNL LSO, the Hazards Control Department, the LLNL Institutional Review Board, Property Management, Procurement, Shipping and, in some instances, the Department of Energy. Depending on the nature of the offsite operation (contract, subcontract, work agreement, gift, property transfer, etc.), an IWS, offsite OSP, or a review may be needed. Offsite

activities for which LLNL has full or partial management responsibility of the activity, or where LLNL will be the primary operators of the laser, require preparation of an IWS and a Level B OSP.

12.1 Lasers Provided to Offsite Organizations

On occasion, LLNL lends lasers and laser systems to offsite organizations or individuals or provides them as part of subcontracts, purchase orders, integrated contractor orders, intra-university transactions, consultant agreements, bailments, cooperative agreements, or for disposal. Program personnel requesting lasers to be drop-shipped or acquired by a subcontractor under an agreement shall inform the LSO. Before an LLNL organization can provide lasers or laser systems to an offsite organization or to an individual, all lasers and laser systems belonging to, or acquired by LLNL (with some exceptions) shall have an LSO evaluation. This evaluation may be documented as an authorization for shipment, and shall be included with both the Shipping and Property Management documentation of the transaction.

Exceptions to the required LSO evaluation involve unmodified, commercially available consumer products, such as laser pointers, laser gunsights, laser printers, compact disk players, and bar-code scanners, or units being returned to the original manufacturer or qualified service company for repair, maintenance, warranty work, modification, or similar circumstances.

12.2 LLNL Modifications or Laser Manufacture

LLNL is considered to be a "manufacturer" by federal regulations if one or more conditions below are met:

- LLNL personnel assembled a laser from parts.
- LLNL personnel modified a commercially available laser or laser system so that the output or safety characteristics have been changed (for better or worse).
- LLNL personnel embedded or incorporated a commercially available or LLNL-built laser or laser system into some type of an LLNL-built laser system.

Note that the laser hazard classification (Class 1, 2, 3a, 3b, or 4) is **not** taken into consideration when determining if LLNL is a manufacturer or not.

The Responsible Individual shall notify the LSO whenever an LLNL-manufactured laser is to be sent offsite. If the LSO's written evaluation determines that any of the conditions above apply, the system shall either be

- "Certified" by the FDA/CDRH and shown to comply with federal 21CFR 1040, "Performance Standards for Light Emitting Products,"

OR

- "Exempted" from the compliance process (21 CFR 1010.5) by the DOE, which has the authority to grant an exemption from the federal product regulations if the laser system is to be used for "government purposes" (i.e. research, investigations, studies, demonstration, training or reasons of national security).

Once a requester has identified a need to send an LLNL-manufactured laser offsite, the requester should contact the LSO as soon as possible to ensure the evaluation or DOE exemption process does not hold up the shipment. Information about certification and exemption is available from your area ES&H Team and LLNL LSO. These individuals also can provide assistance in the process.

Note: An evaluation shall be made by the LSO to determine whether an exemption or certification may apply.

12.3 Shipment Process

Before providing a laser to an offsite organization, the requester shall contact the LSO and obtain written approval. The LSO evaluates the request, prepares documentation outlining the hazards associated with the laser, and concurs with the request.

The requester attaches the LSO's review to documents authorizing the equipment to be sent offsite. Depending on the type of transaction, these documents could include a loan or transfer request, subcontract, intra-university transaction, integrated contractor order, consultant agreement, or any other type of agreement. Drop shipments to offsite organizations shall be evaluated and approved by the LSO.

Offsite organizations that receive a Class 3b or 4 laser but do not have an appointed LSO shall be informed, in writing, of the need to appoint one and to create a Laser Safety Program.

12.4 LLNL Operation of a Laser Offsite

Lasers and laser systems to be operated under the control and custody of LLNL while in use offsite shall be evaluated by the LSO. An IWS and a Level B OSP shall be prepared for the laser operation (except for laser pointers and bar-code scanners, and activities normally performed by the public).

12.5 Joint Operation of a Laser Offsite

An offsite OSP shall be prepared for any LLNL-owned laser system of Class 3a (except for laser pointers and bar-code scanners, and activities normally performed by the public), Class 3b or Class 4 laser jointly operated offsite by LLNL personnel and employees of an offsite organization.

13.0 Return on Site of LLNL Lasers or Laser Systems

LLNL normally expects DOE/LLNL property to be returned for future use at LLNL. Other disposition options are possible if they are more cost effective or if there is a benefit to LLNL and DOE. Property Management and the LSO shall be contacted as soon as possible if you are considering not returning lasers or laser systems to LLNL. However, this optional disposition provision does not apply to DOE-exempted lasers or systems (Section 12.2). DOE-exempted units shall be returned to LLNL and shall not be reused, sold, disposed of, or otherwise introduced into commerce offsite without proper FDA/CDRH certification. Notify the LSO when all laser systems are returned onsite.

14.0 Disposition by the Donation, Utilization and Sales (DUS) Group at LLNL

All lasers and laser systems should be evaluated for toxic or hazardous components by the area ES&H Team prior to their disposal or movement to DUS salvage yard. Lasers and laser systems shall not be given to, or moved offsite, to any other organizations from DUS without an evaluation by the LSO. The area ES&H Team can contact the LLNL LSO for the evaluation.

15.0 Responsibilities

General responsibilities for all workers are described in Document 2.1 . Specific responsibilities for lasers are listed under each title.

15.1 Responsible Individual

Authorizing management shall appoint a Responsible Individual for all areas where Class 2 or higher lasers are operated.

The Responsible Individual should

- Provide workers an opportunity to participate in the hazards analysis and the development of controls.
- Review applicable Lessons Learned.

The Responsible Individual shall validate that

- Individuals working in the area have received proper training in laser safety and other applicable safety classes for the operation.
- Personnel receive eye examinations when required, and schedule the eye exam in a timely manner, before the person begins work.

The Responsible Individual shall ensure

- The safe operation of lasers in the area assigned.
- All individuals, including outside service contractors, understand the hazards associated with lasers and comply with all safety requirements and OSPs.
- Changes to OSPs under their responsibilities are submitted when conditions warrant (when new lasers are added, changes in hazard levels, etc.).
- When appropriate, a hazards assessment is documented on the IWS or Safety Plan to identify the appropriate PPE for use with lasers.

The Responsible Individual shall provide personal protective equipment and ensure that it is used properly.

15.2 Facility Management

- Inform the Responsible Individual, operators, and workers of any facility-specific hazards and controls that may interfere with the safe operation of the lasers to be installed or used in the facility.
- Evaluate the IWS to ensure that the laser operation is within the facility safety envelope and is compatible with other work activities in the area.
- Coordinate with the Responsible Individual if facility modifications are required for work involving the proposed lasers.

15.3 Payroll Supervisors

- Verify that individuals working in the area have received proper training in laser safety and other applicable safety classes for the operation.
- Ensure personnel receive eye examinations when required.

15.4 Laser Operator

- Take laser safety training.
- Comply with the applicable OSPs, procedures, requirements, and controls given in this document.

15.5 Workers

- Keep the Responsible Individual assigned to their area fully informed of any departure from established OSPs.
- Make sure they are current in laser safety and related training.
- Report the following events to their area ES&H Team and the Responsible Individual, and go to the Health Services Department:
  - All laser exposures to the eye or skin that are greater than the MPE for the actual exposure duration. Workers shall contact the LSO through the ES&H Team for the appropriate MPE.
  - Exposures that cause a burning sensation or a change in the condition of the skin, visual afterimage, blurring, obstruction of vision, headaches or other pain.
  - Any injury caused by laser support equipment, such as electric shock or exposure to dye solution.

Note: If any of these events occur after normal working hours, workers shall contact the Emergency Management Division dispatcher at 911.

15.6 ES&H Team

- Assist the Responsible Individual in assuring that safety requirements are followed and in evaluating and controlling hazards.
- Recommends proper PPE.

15.7 Health Services Department

The Health Services Department is responsible for the Laser Medical Monitoring Program.

15.8 Laser Safety Officer

- Oversee the LLNL Laser Safety Program.
- Evaluate laser hazards and installations.
- Establish laser control measures.
- Review laser-related OSPs
- Approve personal protective equipment.
- Assure that adequate training courses are being provided to personnel using lasers.
- Conduct self-assessments of the Laser Safety Program.
- Remain current with and serve as the subject-matter expert (SME) for the applicable Work Smart Standards (WSS).
- Evaluate and approve modifications to lasers and lasers being moved offsite (section 12.0).

The LSO may delegate these duties to an industrial safety engineer assigned to an ES&H Team, who shall serve as a Deputy LSO. Formal Laser Safety Officer training is required; see the LSO for details. The Deputy LSO may be reached through the area ES&H Team.

15.9 Directorate/Program Laser Safety Officer

Directorates or Programs may request that one or more of their personnel be designated as a Directorate/Program Laser Safety Officer. The Directorate AD (or designated representative) shall nominate personnel for this position based upon their knowledge of lasers, the applicable codes and standards, and experience. The LLNL LSO will review the qualifications of the nominees and either accept or reject the nominee(s). Formal Laser Safety Officer training is required; see the LLNL LSO for details. Directorate/Program Laser Safety Officers, under the direction of the LLNL LSO, may exercise the roles, responsibilities, and authorities listed for the LSO (except for overseeing LLNL Laser Safety Program, interacting with external agencies, and serving as the SME for the WSS).

16.0 Work Standards

10 CFR 1046, "Physical Protection of Security Interests."

21 CFR 1002, "Records and Reports."

29 CFR 1910, Subpart J, "General Environmental Controls, and Subpart S, Electrical."

ANSI Z136.1-1993, "American National Standard for Safe Use of Lasers."

ANSI Z136.2-1997, "American National Standard for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources."

DOE O 440.1A, "Worker Protection Management for DOE Federal and Contractor Employees," Attachment 2, "Contractor Requirement Document," Sections 1–11, 13–16, 18 (delete item 18.a) 19 (delete item 19.d.3) and 22.

UCRL-AR-129189, Rev.1, *LLNL Occupational Medicine Standard: Medical Evaluation of Employees*.

NFPA 70, "National Electrical Code."

17.0 Resources for More Information

17.1 Contacts

For further information on laser safety, contact your area ES&H Team or the LSO. The ES&H Teams and the LSO may be contacted by calling the Hazards Control Department.

17.2 Applicable Lessons Learned

Lessons Learned pertaining to laser issues can be found at the following Internet address:

http://www-r.llnl.gov/llnl_only/es_and_h/lessons/lessons.shtml

17.3 Other Sources

21 CFR 1010, "Performance Standards for Electronic Products."

21 CFR 1040, "Performance Standards for Light Emitting Products."

ANSI Z535.2-1998 "American National Standard for Environmental and Facility Safety Signs."

ANSI Z535.4-1998 "American National Standard for Product Safety signs and labels."

NFPA 115 (1995), "Recommended Practice on Laser Fire Protection."

Appendix A

General Layout of Laser Warning Signs

Examples of typical laser signs are shown below in a typical 8.5-x 11-in. horizontal format. Signs shall be conspicuously displayed in locations where they best will serve to warn onlookers. A pragmatic alternative to expensive commercial or laminated signs are ones that can be generated and readily updated with very specific messages using a color printer and mounted in protective viewgraph sleeves. Signs should be approved by an LSO or Deputy LSO and may be obtained from your local ES&H Team. Equipment labels follow basically a similar format as the signs described below. These may also be obtained from your local ES&H Team.

Sign types. The DANGER sign is to be used to indicate an imminent hazard which, if not avoided, ***will*** result in serious injury or death. The CAUTION sign indicates a hazardous situation that ***could*** result in minor or moderate injury if not avoided. The WARNING sign may be used outside an area or an enclosure that contains a danger-level hazard. The ***hazard could potentially*** result in serious injury or death if not avoided. A WARNING sign is not a replacement for the required DANGER sign. The *NOTICE* sign indicates a statement related to personnel or property protection. It shall not be used solely in place of the previously mentioned signs.

Type format. The signal word shall be large type and in all uppercase letters (in this case 108 point), comparable in size to the safety-alert symbol. The word and symbol shall be on the same baseline. The text messages for Positions 1, 2, and 3 shall be 18 or 24 point, left justified using upper and lowercase black letters. Only words that need to be emphasized should be in all capital letters. Do not overfill the space with large type because sufficient "white space" makes the messages more readable. Both the signal word and the messages shall be in bold, sans-serif fonts (Helvetica or Geneva).

Panels and symbols. The upper colored, signal-word panel shall be red to signify DANGER, yellow for CAUTION, orange for WARNING and blue for *NOTICE*. The signal word type shall be white for DANGER and NOTICE, and black for CAUTION and WARNING. Note that only the *NOTICE* word is printed in italic font. The safety-alert symbol uses the corresponding colors as the colored panel; the exclamation point utilizes the same color as the panel; and the equilateral triangle uses the same color as the signal word. The safety-alert symbol is used only to indicate a potential personnel injury hazard. It should not be used to alert only potential property damage. Hence, the *NOTICE* sign does not use a safety alert symbol. The body of the sign may incorporate many different kinds of graphic symbols depending on the type of hazard. The examples below show only the laser sunburst symbol; it shall be black for all signs, except that the DANGER sign shall be red. The *NOTICE* sign may use a black or blue symbol. The

backgrounds for all signs shall be white, except for the CAUTION sign, which uses yellow. In the latter case, the yellow background and signal word panel merge together.

Specific applications of laser-related signs. For the laser-class signs, the word message in Position 1 is verbatim from Section 4.7.4 of ANSI Z136.1-1993 and is based on the highest class of laser described by a sign. Use of the words invisible or visible, as appropriate, are added for any of the lasers covered. If a sign covers only visible lasers, the words visible laser radiation may be replaced by visible laser light. A separate paragraph at Position 1 can describe precautionary instructions. However, it is better to include it just below the sunburst at Position 2. This paragraph may include such messages as "Access for authorized individuals only"; "Minimum optical density (OD) eyewear may be required"; "Knock for access permission"; "Call x-xxxx for access"; etc. It should end with reference to an applicable OSP, FSP or IWS (see OSP xxx.xx) or (see IWS xxxxxxxx) as appropriate. The lower portion of Position 2 should describe either (1) laser type or wavelength, pulse duration (if appropriate) and maximum output; or preferably (2) laser type, OD requirement for maximum protection, applicable wavelength in nm. The latter format is preferred because the OD specification normalizes hazard levels that otherwise would require power (CW) or energy (pulsed), pulse duration and repetition rate as applicable, exposure duration, beam size, divergence, limiting aperture, as well as wavelength. The data should be presented in tabular form for ease of readability and should not be crowded with overly large type. Position 3 shall show the highest class of laser covered by a sign and be located at the lower right-hand corner.

Specific functions of signs are listed below

- A DANGER—Class 4 laser sign covers one or more Class 4 lasers that are considered to be at very high power or energy. Typically, a facility described by such a sign will require access interlocks unless other controls are implemented.
- A DANGER—Class 3b laser sign covers one or more Class 3b lasers that are considered to be of moderate to high power or energy. A facility described by such a sign may employ optional access interlocks, particularly if two or more lasers are in operation at the same time, unless other controls are implemented. Visible CW alignment lasers ≤15 mW and with appropriate beam control require no interlocks when they are the only lasers used.
- A DANGER—Class 3a laser sign covers one or more Class 3a lasers that are considered to be of moderate power or energy and exceed the maximum permissible exposure (MPE). Typically, a facility described by such a sign will not employ access interlocks.
- A CAUTION—Class 3a laser sign covers one or more visible Class 3a lasers that are considered to be of low power or energy and are expanded not to exceed

the MPE when viewed without optical viewing aids for ≤0.25 s. This sign is seldom used. No interlocks are required.

- A CAUTION—Class 2 laser sign covers one or more visible Class 2 lasers that are considered to be of low power and do not to exceed the MPE for ≤0.25 s. No interlocks are required.
- A WARNING sign warns of potential harm behind a door or enclosure. It may be used to advise of an unattended operation; a high-power or high-energy laser completely embedded as a Class 1 laser; hazardous accessible electrical contacts within an enclosure, etc.
- A *NOTICE* sign is a policy sign conveying information directly or indirectly related to personnel or property protection. It may provide notification of inactivity of a facility, equipment, or an interlock system. It may also be used to advise of a temporary situation such as when a laser is being serviced without functioning interlocks. In the latter case, the *NOTICE* sign must be supplemented with the appropriate DANGER sign.

Figure A-1 Displays a generic sign with the following general characteristics (from top to bottom): at the top is a colored signal-word panel with a safety-alert symbol (exclamation point within an equilateral triangle) and a signal word; below this is a word message designated as Position 1; this is followed by a graphic symbol (in this case, a laser-sunburst symbol); positions 2 and 3 are final word messages. Older signs that conformed to ANSI standards shall remain valid; however, all new signs shall conform to the new sign standards described in ANSI Z535.*x*-1998 (*x* refers to standards 1, 2, 3, 4 and 5).

Appendix B

Safety Issues when Preparing a Beam Alignment Procedure

If an alignment procedure is recommended or required, use the following as a guide for items that may need to be considered in your particular application. Include in the procedure situations or steps during the alignment where there may be a possibility of exposure. Document 3.4, "Preparation of Work Procedures," in the *ES&H Manual* describes the process to prepare a procedure, including a laser alignment procedure.

- ACCESS—To avoid injuries and embarrassing incidents, make sure that unauthorized people are not present and cannot enter the lab any time-an alignment is being conducted.
- BUDDY SYSTEM—When working with Class 4 lasers either use the buddy system or develop a working-alone policy.-When exposed to Class 2 or above electrical hazards, never work alone; use the buddy system as specified in Document 16.1, "Electrical Safety," in the *ES&H Manual*.
- PREPARATION—To make alignment as quick and easy as possible, locate all equipment and materials needed prior to beginning the alignment. Put surplus materials on the table away to minimize the risk of stray specular reflections and non-beam accidents.
- REDUCED BEAM POWER—During alignments, use a Class 2 or 3a coaxial alignment laser or run the laser at the lowest useful power. Avoid going to full power as much as possible during alignments.
- PERSONAL PROTECTIVE EQUIPMENT (PPE)—Identify the PPE to be used. For visible light, use laser protective eyewear with the maximum optical density (OD) that still allows the wearer to view necessary diffuse reflections. For chronic exposures, cover the skin with a lab coat, gloves, and if necessary, a UV face shield to protect from scattered ultraviolet light (UV).
- BEAM CONTROL—Close the laser shutter while conducting crude adjustments of optics or when entering the beam path. Make sure that the optics are secure prior to opening the shutter. Clearly mark beams that leave the horizontal plane. Terminate stray beams.
- INVISIBLE BEAMS—Use viewing aids (e.g., IR cards and viewers) or fluorescent materials (e.g., colored pieces of paper or Polaroid sheets). Note that IR cards and Polaroid sheets may be specular reflectors. Avoid alignment using invisible beams as much as possible by using a visible coaxial laser.
- PULSED LASERS—Align by firing pulses one at a time, if practical.

- INTRABEAM VIEWING—Avoid intrabeam viewing. If intrabeam viewing is required, use a remote viewing camera.
- RESTORING NORMAL CONTROLS—When alignment is complete, make sure that all beam blocks/barriers, interlocks, and enclosures are replaced and working.

Document measures taken to ensure that there are no hazardous specular reflections present when reduced optical densities are used during alignments. This might entail first looking for high-intensity beams using alignment aids while wearing full eyewear protections. Once these beams are identified, eyewear OD may be reduced with alignment eyewear in a stepwise fashion searching for lower intensity stray beams.

Appendix C

Ordering Laser Eyewear

Laser eyewear can be purchased in various frame styles, with or without prescription, adjustable or non-adjustable. Contact your area ES&H Team industrial Safety Engineer to find the frame style best suited to your needs. Your ES&H Team industrial safety engineer can also recommend vendors that have reputable quality assurance programs in place for the eyewear that they sell.

C.1 Prescription Orders for Safety Glasses

Prescription eyewear is issued to a single individual and requires a prescription no older than one year from your ophthalmologist or optometrist.

Step	Who Does It	What Is Done
1	Laser experimenter, laser operator and area Industrial Safety Engineer	Calculate or confirm the required optical density. Select the appropriate frame style.[a]
2	Laser experimenter, laser operator	Fill out two forms: • "Information Needed To Obtain Laser Eyewear" (Figure C-1). • Form LL 2588, "Authorization for Safety Glasses" (Figure C-2). This form is available at the following Internet address: http://www-r.llnl.gov/eforms/eforms_lib.html
3	Technical Release Representative (TRR)	• Approves purchase of laser glasses by filling in an account number and signing the forms. • Sends form to Safety Glasses Office, L-723.
4	Safety Glasses Office/ Industrial Optometrist	Reviews completed forms and orders safety glasses.
5	Safety Glasses Office/ technician	• Receives the glasses from the manufacturer. • Schedules a fitting. At fitting appointment: Checks the glasses for the proper prescription and Optical Density. Discusses proper care and use of the laser eyewear with you.

[a] The industrial safety engineers also have access to various frame styles that can be fitted with glass or plastic lenses as well as styles that can be worn over your present glasses and have been trained to help you select the frame style that provides the best fit for the best protection.

Prescription laser eyewear is exclusively ordered through the Safety Glasses Office TRR and must be properly fitted by the Industrial Optometrist at the Safety Glasses Office (ext. 2-5190).

C.2 Ordering Non-prescription Safety Glasses

Non-prescription laser eyewear may be worn by more than a single individual, possibly over the wearer's prescription glasses, and be adjusted for fit by the wearer. This type of eyewear may be ordered by any TRR, following evaluation and approval by the area industrial safety engineer or LLNL LSO.

Stage	Who Does It	What Is Done
1	Laser experimenter, laser operator and area Industrial Safety Engineer	• Calculate or confirm the required optical density. • Select the appropriate frame style.[a]
2	Laser experimenter, laser operator	Fill out two forms: • "Information Needed To Obtain Laser Eyewear" Figure C-1). • Form LL 2588, "Authorization for Safety Glasses" Figure C-2). This form is available online at http://www-r.llnl.gov/eforms/eforms_lib.html
3	Technical Release Representative (TRR)	• Approves purchase of laser glasses by filling in the account number and signing. • Sends form to Industrial Safety Engineer who processed the request.
4	Industrial Safety Engineer	Reviews completed forms and order safety glasses.
5	Industrial Safety Engineer	• Receives the glasses from the manufacturer. • Schedules an appointment: • Checks the glasses for the proper Optical Density. • Discusses proper care and use of the laser eyewear with you.

[a] The industrial safety engineers also have access to various frame styles that can be fitted with glass or plastic lenses as well as styles that can be worn over your present glasses and have been trained to help you select the frame style that provides the best fit for the best protection.

Information Needed to Obtain Laser Eyewear

*Please fill in a separate sheet for **each** type of eyewear you seek.*

I. Optical density and wavelength information is essential. Please fill in the following table for the eyewear you want:

	Laser or wavelength 1	Laser or wavelength 2	Laser or wavelength 3	Laser or wavelength 4
Laser name				
Wavelength				
CW or pulsed?				
Output power (CW)				
Pulsed only				
Output energy per pulse				
Pulse duration				
Pulse repetition rate				

NOTE: Be sure to account for unexpected exposures to fundamentals/harmonics when specifying eyewear for frequency-converted lasers.

Is this laser operation covered by a Safety Plan (SP) or IWS? Yes ☐ No ☐.

If it is covered by an SP, what is the number of the SP?_____

II. User needs and preferences should be discussed with the Laser Safety Officer before ordering eyewear. The following information is needed:

A. Prescription (check one) No ☐ Single vision ☐ Bifocal ☐

B. *Goggles* or *spectacles* (check one) Goggles ☐ Spectacles ☐

C. For *spectacles*, should opaque side shields or translucent side shields that will still block the laser wavelengths will be ordered? (check one)

Opaque side shield ☐ Translucent side shield ☐

D. Do you want glass lenses or plastic lenses?

1. Glass lenses are usually heavier, but usually let through more light and are more resistant to damage when struck directly by a beam.

2. Glass lenses are used when average output ≥100 W and for prescriptions.

   (check one) Glass filters? ☐ Plastic filters? ☐

E. *For eyewear to be worn over existing glasses*: Goggle or wraparound laser eyewear can be used, but some goggles may be too small for some fashionable big-lens street spectacles. (Check one)

   Doesn't apply ☐ Prefer goggles ☐ Prefer wraparounds ☐

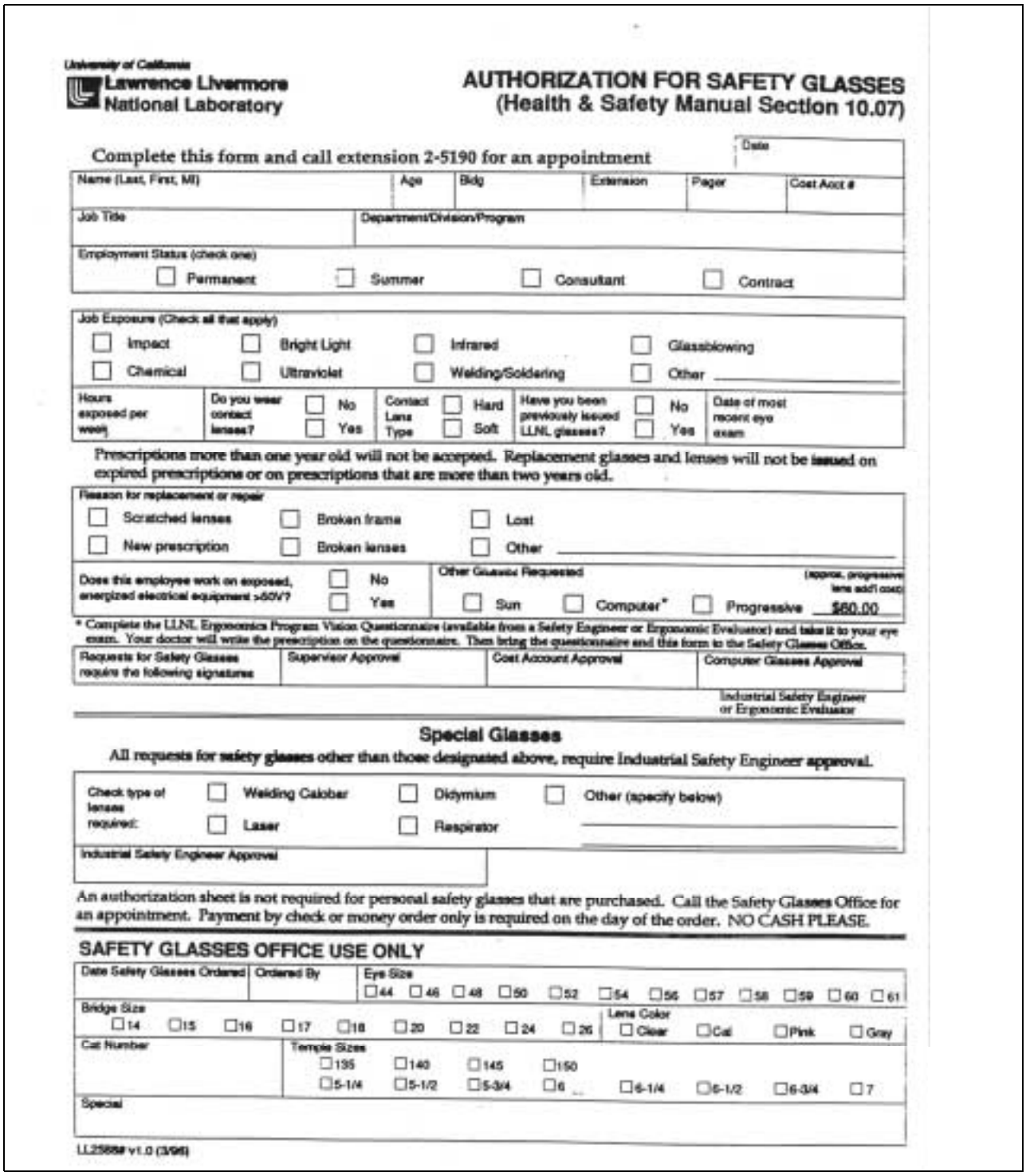
F. *For multiple wavelengths requiring several filter layers* (glass filters only):

1. The two filter materials can be glued together so protection is always provided against multiple wavelengths.
2. Alternatively, when exposures to one wavelength occur more frequently, the filters for the wavelength with fewer exposures can be provided as a *flip up* or *clip on*. (Check one of the following)

   Single wavelength/band only ☐ Flip up ☐ Clip on ☐ Glued together ☐

III. How many pairs do you need?_____

Figure C-1. Information Needed to Obtain Laser Eyewear Form.



University of California
Lawrence Livermore National Laboratory

AUTHORIZATION FOR SAFETY GLASSES
(Health & Safety Manual Section 10.07)

Complete this form and call extension 2-5190 for an appointment

Date

Name (Last, First, MI)	Age	Bldg	Extension	Pager	Cost Acct #

Job Title	Department/Division/Program

Employment Status (check one)
☐ Permanent ☐ Summer ☐ Consultant ☐ Contract

Job Exposure (Check all that apply)
☐ Impact ☐ Bright Light ☐ Infrared ☐ Glassblowing
☐ Chemical ☐ Ultraviolet ☐ Welding/Soldering ☐ Other _____

Hours exposed per week	Do you wear contact lenses? ☐ No ☐ Yes	Contact Lens Type ☐ Hard ☐ Soft	Have you been previously issued LLNL glasses? ☐ No ☐ Yes	Date of most recent eye exam

Prescriptions more than one year old will not be accepted. Replacement glasses and lenses will not be issued on expired prescriptions or on prescriptions that are more than two years old.

Reason for replacement or repair
☐ Scratched lenses ☐ Broken frame ☐ Lost
☐ New prescription ☐ Broken lenses ☐ Other _____

Does this employee work on exposed, energized electrical equipment >600V? ☐ No ☐ Yes

Other Glasses Requested (approx. progressive lens add'l cost)
☐ Sun ☐ Computer* ☐ Progressive $60.00

* Complete the LLNL Ergonomics Program Vision Questionnaire (available from a Safety Engineer or Ergonomic Evaluator) and take it to your eye exam. Your doctor will write the prescription on the questionnaire. Then bring the questionnaire and this form to the Safety Glasses Office.

Requests for Safety Glasses require the following signatures	Supervisor Approval	Cost Account Approval	Computer Glasses Approval

Industrial Safety Engineer or Ergonomic Evaluator

Special Glasses

All requests for safety glasses other than those designated above, require Industrial Safety Engineer approval.

Check type of lenses required:
☐ Welding Calobar ☐ Didymium ☐ Other (specify below)
☐ Laser ☐ Respirator _____

Industrial Safety Engineer Approval

An authorization sheet is not required for personal safety glasses that are purchased. Call the Safety Glasses Office for an appointment. Payment by check or money order only is required on the day of the order. NO CASH PLEASE.

SAFETY GLASSES OFFICE USE ONLY

Date Safety Glasses Ordered	Ordered By	Eye Size
		☐44 ☐46 ☐48 ☐50 ☐52 ☐54 ☐56 ☐57 ☐58 ☐59 ☐60 ☐61

Bridge Size
☐14 ☐15 ☐16 ☐17 ☐18 ☐20 ☐22 ☐24 ☐26

Lens Color
☐Clear ☐Cat ☐Pink ☐Gray

Cat Number	Temple Sizes
	☐135 ☐140 ☐145 ☐150 ☐5-1/4 ☐5-1/2 ☐5-3/4 ☐6 ☐6-1/4 ☐6-1/2 ☐6-3/4 ☐7

Special

LL2568# v1.0 (3/98)

Figure C-2. Authorization for safety glasses.

Appendix D

Terms and Definitions

Accessible radiation	Laser radiation to which it is possible for the human eye or skin to be exposed during normal use.
Authorized person	A person who has the approval of the area supervisor and/or program management to perform a particular function in that area.
Aversion response	Movement of the eyelid or the head to avoid exposure to a noxious stimulant or bright light. An aversion response can occur within 0.25 s, including the blink reflex time.
Continuous-wave (CW) laser	A laser operating with a continuous output for a period that is greater than or equal to 0.25 s.
Controlled laser area	An area where the occupancy and activity of those within are subject to control in order to protect personnel from hazards.
Commerce	Organizations or individuals that are not part of the DOE or DOE contractors.
Diffuse reflection	Spatial distribution of a beam of radiation when it is reflected in many directions by each point on a surface or within a medium.
Embedded laser	A laser with an assigned classification higher than the classification of the laser system in which it is incorporated. The system's lower classification is appropriate because engineered features limit accessible emission.
Enclosed laser	A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place. An embedded laser is an example of one type of enclosed laser.

Failsafe	An electrical or mechanical system where the failure of a single component of the interlock will cause the system to go into, or remain in, a safe mode.
Irradiance (E)	The optical power per unit area reaching a surface (W/cm^2).
Joule (J)	A unit of energy (1 Joule = 1 Watt-second).
Laser, laser system	A device that produces an intense, coherent, directional beam of light. Also an acronym for Light Amplification by Stimulated Emission of Radiation. A laser system is a device that has an attached laser, lenses, and mirrors or fiber optics, or somehow uses the exposed beam of the attached laser.
Laser Safety Officer (LSO)	The LSO is appointed by the Hazards Control Department Head. He or she is charged with the knowledgeable evaluation and control of laser hazards that are due to LLNL operations. If the LSO is unavailable, a Deputy LSO (i.e., an ES&H Team industrial safety engineer that has had formal Laser Safety Officer training) shall perform these functions.
Maximum permissible exposure (MPE)	The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The LSO can provide guidance on calculating an appropriate MPE or a copy of the standard.
Nominal hazard zone (NHZ)	The space around a laser in which exposure to laser light exceeding the MPE is possible. The space boundary shall be clearly indicated by signs, barricades, walls, and ropes, as appropriate (e.g., the laboratory walls and doors typically satisfy this requirement).
Offsite	Outside the LLNL or Site 300 fence line.
Power	The rate at which energy is emitted, transferred, or received. The unit of measurement used is *watt* or *Joules per second*.

Pulsed laser	A laser that delivers its energy in the form of a single pulse or a train of pulses, with a pulse duration of less than 0.25 s.
Radiant exposure	The optical energy per unit area reaching a surface (Joules/cm^2).
Reflection	The deviation of radiation following incidence with a surface.
Specular reflection	A mirror-like reflection.